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Simulation, Design and Implementation of Solar Power Optimizer for DC Distribution System using Coupled Inductor and Switched Capacitor

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***Abstract*— This paper proposes use of a high step up solar power optimizer (SPO) that efficiently reaps maximum energy taken from photo voltaic (PV) panel fed to a DC-micro-grid. The proposed converter employs a switched capacitor and coupled inductor, by varying duty ratio and turns ratios generally we want for the coupled inductor to achieve high step up voltage conversion; The leakage inductance energy of the coupled inductor is efficiently to the load and reduce voltage stress. A rating of low voltage and low-conduction resistance switch makes the system efficiency by employing the perturb and observe (P and O) method for the maximum power point tracking the operating principles and continuous and discontinuous modes , as well as the voltage and current stress of the active switch components are investigated in detail. A 20V to 40V input voltage, 400V output voltage and 300W output power simulation configuration of the proposed system is implemented to verify the feasibility. The simulation is carried over by the MATLAB-SIMULINK software**

Keywords*— *Coupled inductor, high step-up converter, single switch, solar power optimizer (SPO).

I. INTRODUCTION

Generally a photovoltaic power generation system is used as a renewable resource; it has been used in emergency facilities and generating electricity. This PV power generation system needs to be high efficiency and high reliability. A conventional photovoltaic generation system is either a single or a PV array is connected to one or few central PV inverters. The PV modules are connected in series with the PV array to obtain the Dc link voltage that is high enough to electricity connected fed to the DC-ac inverter. However the reduction of power is caused by effect of the shadow. That is problem of centralized photo voltaic system. The micro-grid or AC modules are using in recent days for separate PV panels [1], [2]. Although this PV power generation of shadow problem solution may partially eliminate, the structure of the micro inverter constrains the system energy's reaping efficiency and cost is high.

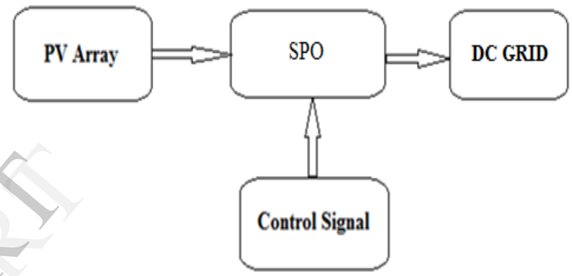


Fig. 1 General block diagram of the proposed system

An alternative proposed solar power optimizer is developed to reap maximize energy taken from separate photovoltaic modules. A DC-DC convertor is used in solar power optimizer with maximum power point tracking. The PV panel voltage increases rapidly to optimum voltage levels and a DC micro-grid connection for the electricity of DC-AC inverter [3]-[6]. A single PV panel's energy is shown in Fig. 1. This power passes through an SPO to a DC micro-grid system. The 40V input voltage fed to SPO. This SPO will produce high step up voltage of 400V DC using boost converter, this output of micro-grid distribution for data centre systems and telecommunication facility [7]. These are the attempts of SPO to improve the overall system of renewable resources and system cost is lower, has an anti-shadow effect of PV system can be monitored and improve the efficiency [8].

A single PV panel voltage range of 20V-40V and capacities of power about 100W-300W are used [9]. A high step up SPO using boost converter, that increases low voltage to required voltage level. The step-up DC-DC converter with various topologies consists of a boost and fly back converters [10][11], switched capacitor and coupled inductor converters and boost type that are investigated with coupled inductor. The floating switch used in SPO because of its increasing voltage gain, the leakage inductance energy of the coupled inductor can be recycled and the voltage stress on the active switch.

II PROPOSED CIRCUIT

Circuit diagram of the proposed SPO is as shown in fig. 2 below.

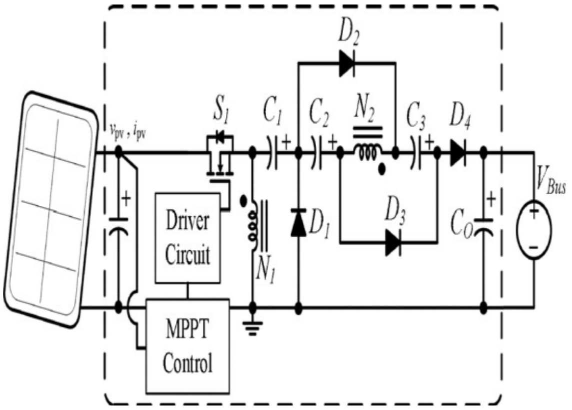


Fig. 2 circuit diagram of the proposed system

This proposed SPO is based on a high step up dc-dc converter with an MPPT control circuit. The converter consists of a drifting active switch S and a coupled inductor T_1 with primary winding N_1, which is comparing to the conventional boost converter capacitor c1 and diode D1 used to recycle the leakage inductance energy from N1. Secondary winding N2 is series connected to the capacitor C2 and C3 and diodes D1 and D2 are parallel connected. The output capacitor connected from rectifier diode D4 and load R. The duty ratios are adjusted by the MPPT algorithm. Which uses perturb and observe method in the proposed SPO. Therefore, the MPPT can be gained by representing a similar instantaneous conductance I/V and perturb and observe dI/dV.

The main three features in proposed converter are as follows:

(1) The voltage transmutation ratio is increased due to coupled inductor and switched capacitor techniques.
(2) Its increase efficiency due to leakage inductance energy of the coupled inductor can be recycle and active switch restrained
(3) During co-operating conditions, the drifting active switch isolates the PV panel's energy.

The MPPT algorithm is widely used in the energy reaping of PV system. Hence it exhibits high tracking efficiency.

III OPERATING PRINCIPLES

There are two operating principles using two modes; first one is continuous conduction mode (CCM) and second mode is discontinuous conduction mode (DCM) are shown in detail. Fig 3 shows several waveforms in CCM operation during active switching period. To describe the proposed converter circuit analysis as following points are mode.

A. CCM OPERATION

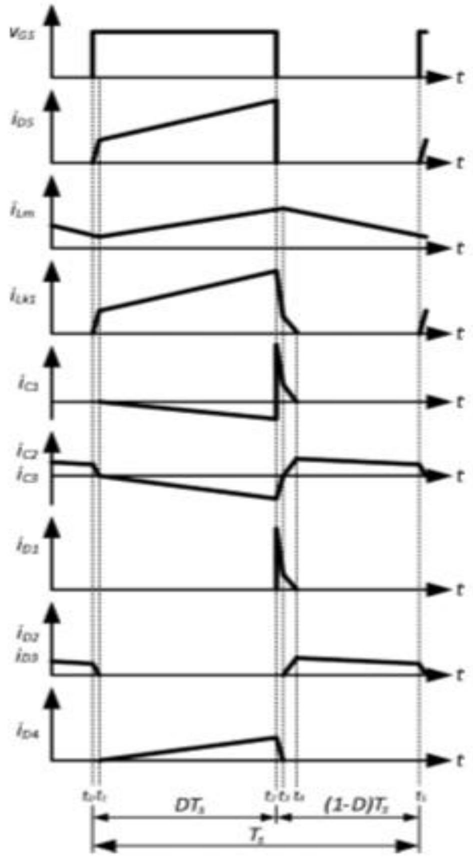
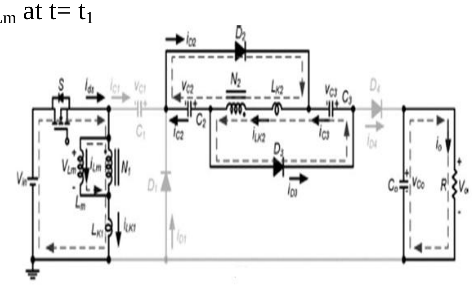
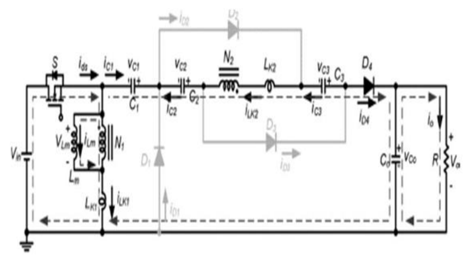


Fig. 3 Waveforms of the proposed converter in CCM operation

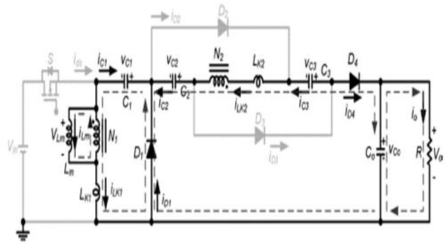
Mode 1 (t_0, t_1): when the switch S and diodes D_2 and D_3 are conducted. While diodes D_1 and D_4 are turned OFF the current flow path as shown in fig 4(a). There is continuity to release energy taken from magnetizing inductor Lm to capacitors C_2 and C_3 via secondary winding N2 of coupled inductor T1. This mode ends when increasing i_{lk1} equal to decreasing i_{Lm} at t= t_1



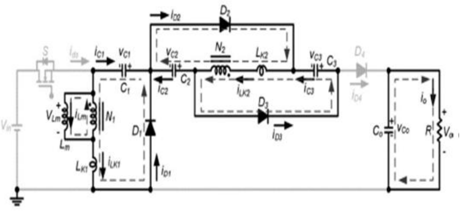
(a)



(b)



(c)



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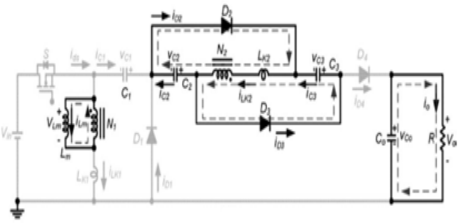


(e)

Fig . 4 Principle operatig modes during one switching period in CCM operation: (a) Mode 1, (b) Mode 2, (c) Mode 3, (d) Mode 4, (e) Mode.

Mode 2 ($t_{1,}$ t_2): when the switches turned ON at the interval of t= t_2 and the diode conducted. Source voltage $_{Vin}$ connected in series with capacitor $C_{1,}$ C_2 and $C_{3,}$ and secondary winding $N_{2.}$ The leakage inductance discharge energy is stored in charge output capacitor and load R. The source energy $V_{in,}$ release to magnetizing inductor l_m also. The current flow path is as shown in fig 4(b).

Mode 3 ($t_{2,}$ t_3): In this mode switch S and diodes D_2 and D_3 are turned OFF and diodes D_1 and D_4 are conducted at t= t_3. The current flow path is as shown in fig 4(c). In this mode capacitor $C_{1,}$ C_2 and $C_{3,}$ are series connected and secondary winding. The magnetizing inductor releases energy taken from leakage inductance through coupled inductance and output capacitor to load R. This mode ends when decreasing i_{lk1} is equal to increasing i_{Lm} to zero at t= t_3.

Mode 4 ($t_{3,}$ t_4): when switch S and diode D_4 are turned off at the interval of t= t_3 & diodes $D_{1,}$ D_2 and D_3 are conducted. The current flow through is as shown in fig 4(d). The release energy of leakage inductance L_{k1} fed to capacitor C_1 by diode. The stored energy in capacitor c_o is discharged constantly to load R. this mode ends when decreasing i_{Lk1} is zero at t= t_4.

Mode 5 ($t_{4,}$ t_5): In this mode diodes D_2 and D_3 are conducted and switch S is turned OFF at the interval of t=$t_{5.}$ The current flow path is shown in fig 4(e). The transfer energy will be released from magnetizing inductor to secondary winding N_2 and charged capacitor C_2.The discharged stored energy from capacitor (Co) to load. The operation completes in this mode and repeats itself.

B. DCM OPERATION

Fig 5 shows a typical waveform of several major components during one switching period in DCM operation.

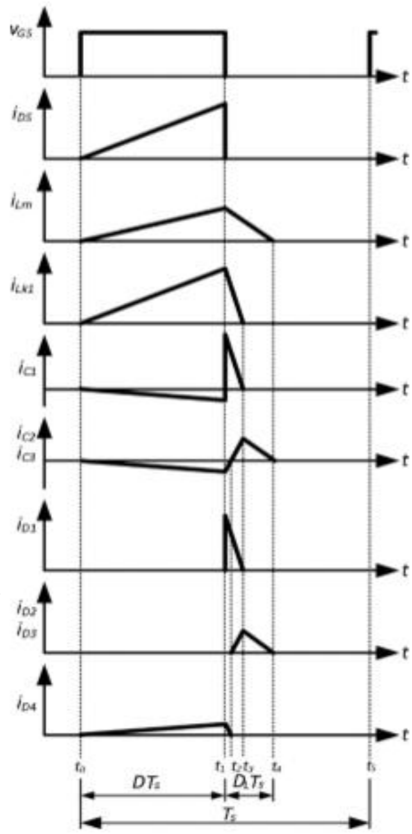
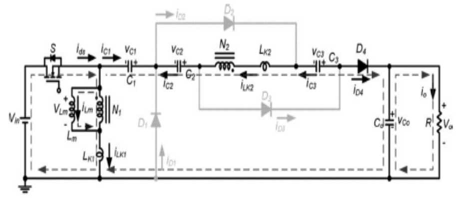
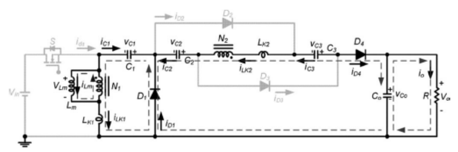


Fig. 5 Waveforms of the proposed converter in DCM operation

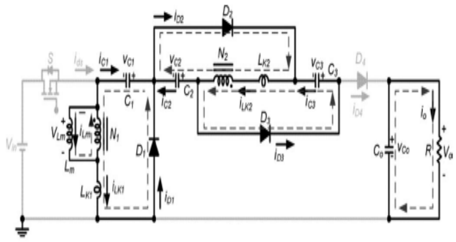
Mode 1 ($t_{0,}$ t_1): When the switch S and diode D_4 are conducted at the interval of t=to & diodes $D_{1,}$ D_2 and D_3 are turned off. The current flow path is shown in fig 6(a). Energy stored in magnetizing inductor with leakage inductance from source energy V_{in}. The capacitor $C_{1,}$ C_2 and C_3 are connected in series with secondary winding to charge capacitor C_o and load R. when switch s is turned off in this mode at t= t_1.



(a)



(b)



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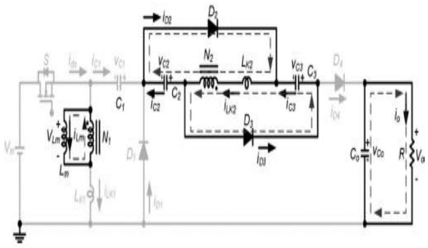

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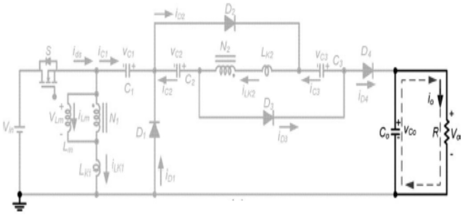


(e)

Fig . 6 Principle operatig modes during one switching period in DCM operation: (a) Mode 1, (b) Mode 2, (c) Mode 3, (d) Mode 4, (e) Mode.

Mode 2 (t_1, t_2): During this mode, switch S and diodes D_2 and D_3 are turned OFF and diodes D_1 and D_4 are conducted at the interval of t= t_1. The current flow path is as shown in fig 6(b), energy stored in leakage inductance L_{K1} connected to charge capacitor through diode D1. This mode also release energy to magnetizing inductor L_m connected to capacitor c1, c2, c3 and secondary winding N2 via coupled inductor L_{K2} to charge output capacitor Co and load R. This mode ends when decreasing, I_{D4} is zero at t= t_2.

Mode 3(t_2, t_3): During this mode, switch S and diode D4 are turned off and diodes D_1, D_2 and D_3 are conducted at the interval of t= t_2 the current flow through this mode is as shown in fig 6(c). The transfer energy to capacitor C2 and c3 via coupled inductor due to magnetizing inductor Lm. The constantly discharged energy stored in capacitor to load. This mode will come to end when decreasing i_{Lk1} is zero at t= t_3.

Mode 4 (t_3, t_4): In this mode, when switch s, diodes D_1 and D_4 are turned off and diode D_2 and D_3 are conducted at the interval of t= t_3. The current flow direction in this mode as shown in fig 6(d).The secondary winding N2 and capacitor C2,C3 taking from transfer energy by magnetizing inductor. This mode release energy by the output capacitor Co to load R. This mode ends when decreasing i_{Lm} is zero at t= t_4.

Mode 5 (t_4, t_5): In this mode, the switch and all diodes are turned off. The current flow direction is as shown in fig 6(e). The capacitor energy stored is discharged to load R. This mode stops when switch S is turned ON.

IV RESULTS

A MATLAB/Simulink programs is used for the simulation of the proposed system. Modelled and analysed the PV panel by using the MATLAB simulation mainly converter part of concentrated for the whole system. Perturb and observe MPPT algorithm is verified in this system. The proposed Simulink model is shown in the fig. 7.

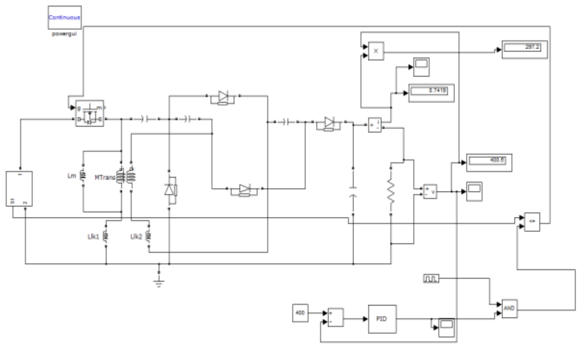
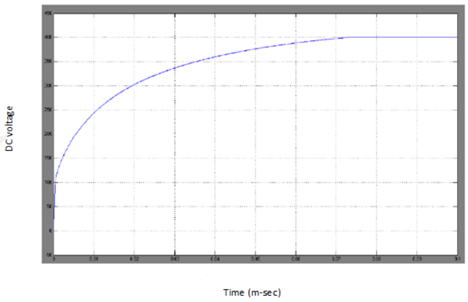
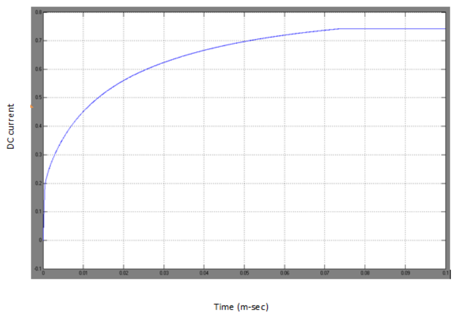


Fig. 7 Simulink model of solar power optimizer



(a)



(b)

Fig. 8 (a) output voltage and (b) output current

The output voltage of the solar power optimozer obtained is 400V and is shown in fig. 8. The input voltage is varied from 20V to 40V. Input current from 6A to 7A. Output current from 0.5A to 0.9A the output voltage of the solar power optimizer is fed to the DC grid. The DC grid voltage is maintained to be of 400V by using solar power optimizer. So the output voltage is maintained constantly at 400V, whatever the input voltage.

V CONCLUSION

The high step up SPO uses boost converter with coupled inductor and switched capacitor technologies. Because of the leakage inductance energy of a coupled inductor is recycled and the voltage stress across the drifting active switch S is constrained and improved overall system efficiency.

REFERENCES

1. W. Yu, J.-S. Lai, H. Qian, and C. Hutchens, "High-efficiency MOSFET inverter with H6-type configuration for photovoltaic nonisolated ac-module applications," IEEE Trans. Power Electron., vol. 26, no. 4, pp. 1253–1260, Apr. 2011.
2. L. Gao, R. A. Dougal, S. Liu, and A. P. Iotova, "Parallel-connected solarPV system to address partial and rapidly fluctuating shadow conditions," *IEEE Trans. Ind. Electron.*, vol. 56, no. 5, pp. 1548–1556, May 2009.
3. R. Gules, J. De Pellegrin Pacheco, H. L. Hey, and J. Imhoff, "A maximum power point tracking system with parallel connection for PV stand-alone applications," *IEEE Trans. Ind. Electron.*, vol. 55, no. 7, pp. 2674–2683, Jul. 2008.
4. B. Liu, S. Duan, and T. Cai, "Photovoltaic dc-building-module-based BIPV system: Concept and design considerations," *IEEE Trans. Power Electron.*, vol. 26, no. 5, pp. 1418–1429, May 2011.
5. W. Xiao, N. Ozog, and W. G. Dunford, "Topology study of photovoltaic interface for maximum power point tracking," *IEEE Trans. Ind. Electron.*, vol. 54, no. 3, pp. 1696–1704, Jun. 2007.
6. L. Zhang, K. Sun,Y. Xing, L. Feng, andH.Ge, "A modular grid-connected photovoltaic generation system based on DC bus," *IEEE Trans. Power Electron.*, vol. 26, no. 2, pp. 523–531, Feb. 2011.
7. S. M. Chen, K. R. Hu, T. J. Liang, L. S. Yang, and Y. H. Hsieh, "Implementation of high step-up solar power optimizer for DC micro grid application,"in*Proc. IEEE Appl. Power Electron Conf.*, Feb. 2012, pp. 28–32.
8. A. Pratt, P. Kumar, and T. V. Aldridge, "Evaluation of 400 V DC distribution telcom and data centers to improve energy efficiency," in *Proc. IEEEInt. Telecomm. Energy Conf.*, Sep./Oct. 2007, pp. 32–39.
9. L. Zhang, K. Sun,Y. Xing, L. Feng, andH.Ge, "A modular grid-connected photovoltaic generation system based on DC bus," *IEEE Trans. Power Electron.*, vol. 26, no. 2, pp. 523–531, Feb. 2011.
10. S.M. Chen, T. J. Liang, L. S. Yang, and J. F. Chen, "A boost converter with capacitor multiplier and coupled inductor for AC module applications,"*IEEE Trans. Ind. Electron.*, Early Access Articles, vol. PP, no. 99, p. 1.
11. A. C. Nanakos, E. C. Tatakis, and N. P. Papanikolaou, "A weighted efficiency-oriented design methodology of flyback inverter for AC photovoltaic modules," *IEEE Trans. Power Electron.*, vol. 27, no. 7, pp. 3221–3233, Jul. 2012.
12. S. Zengin, F. Deveci, and M. Boztepe, "Decoupling capacitor selection in DCM flyback PV micro-inverters considering harmonic distortion," *IEEETrans. Power Electron*, Early Access Articles, vol. pp., no. 99, p. 1.